Short Line Technology For High Performance Automotive Composites

Product Technik believe that the processes for producing cars from advanced composites will remain relatively variable for the foreseeable future. Operations specialists can work with these processes to provide effective solutions for the 3rd generation of composite cars.

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10 years ago the designers of the first generation advanced composites vehicle had a limited choice of processes, such as pre-preg or wet lay up. Designers can now choose from a range of new processes such as SMC, BMC, RTM, film infusion, liquid infusion and thermoplastics. Each process is characterised by a bewildering array of branded acronyms. Each brand has its advocates who trumpet its successes, whilst insiders and competitors mutter darkly about their many problems.

All the material options are capable of delivering at least some of the desired results. As we head for the 3rd generation of advanced composite cars, and another order of cost reduction, we must recognise that complex anisotropic composites have barely existed for one tenth of the time of sheet steel and in comparison the production processes are still complex, slow and variable.

For the next generation of projects to be a success we must guarantee an operating profit, and this means firstly guaranteeing output. Surprisingly it may well be Operations (the way we organise our work) which can offer a solution in the medium term. The approach described in this article was first tried with some success for the production of advanced composites cars some 10 years ago. Until now Operations Management has remained a little understood and somewhat underrated aspect of composites production.

The effect of variability on Flow Lines

When building composites for automotive OEMs, we have naturally tried to imitate the mass production flow line. The product is built step by step as it moves between processes or along a track. The value stream is linear, the material moves from process to process adding value as it progresses. A typical value stream for a body panel, made from film infused materials, contains some 15 sequential processes see fig 2.

Each stage has its own special equipment, specialist workforce, and its own pile of work in

Fig 1 The world first and fasted car made from advanced composites.

progress, comprising of materials waiting for processing and parts being processed. These stages are termed process villages, since each carries out a unique and special process on the road to the final product.

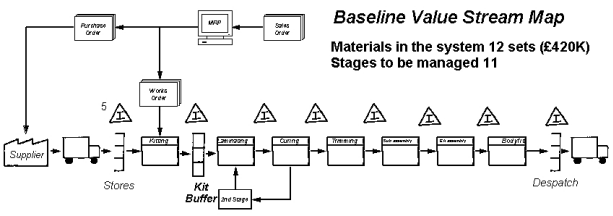

Fig 2 A typical value stream

The capacity of each process village has to be balanced against output and economic batch sizes, and it is here that the high process variability of composites becomes a serious problem. If one

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process village hits a problem it will starve the next of work, while building up a queue of unprocessed work in front of it. The predictive techniques used to control production rely on accurate information and without it the line becomes unstable, reacting like an un-damped spring. Problems move up and down the value stream with lightening speed.

Short Line Technology

When designing the process flow for the first generation of advanced composites cars, Operations specialists could be certain of only 1 thing; that the processes would highly variable. The solution was for Operations to organise the factory in such a way that it was tolerant of problems. So called Short Line Technology was the answer.

Short Line Technology is a mixture of best practices, applied to composites production with the focus of making material flow through the factory to TAKT time. Short Line Technology has no process villages; instead multi-skilled cells are capable of carrying out many of the processes necessary to produce a part or assembly. This makes for many parallel paths and a short value stream. Short value streams are less prone to disruption. Problems are isolated in individual cells where they can be handled while production continues uninterrupted in the other cells.

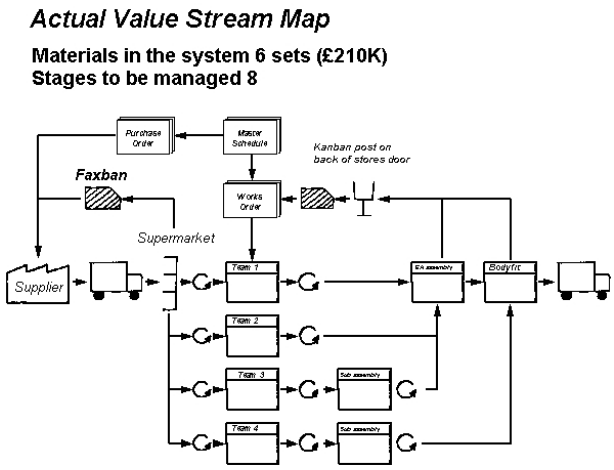

Fig 3 The Short line value stream isolates problems in small cells.

For comparison the short line value stream has only 5 stages. The length of the Short Line Technology value stream is 10 stages shorter than a sequence of process villages.

The issue of equipment utilisation is often taken to be a barrier to short line technology. Time slicing or running major plant such as autoclaves, to a tight schedule with carefully constructed cure schedules make the use of shared resources viable.

Co-variance or The Troop Analogy
(Attributed to Goldratt)

A production line is often likened to a troop of soldiers which can only march at the rate of the slowest. If one soldier trips or stumbles the whole troop must slow down to stay together. The result is always the same, the troop slows down, and thus it is with a production flow line.

The output of a sequential production line can only meet the output of the worst performing process at any one time. This principle is called co-variance, and dictates that process problems will inter-react in such a way that output always suffers. For Operations Managers there is never any good news!

By organising parallel value streams using cells, the work flow can be made less dependant on series process. Now when a soldier trips and falls he can run and catch up, he hasn't held up those following him, and only he needs to run to catch up.

Surprisingly the Operations specialists exploited the now obsolete pre-preg process to make parts in one shot, there was no need to make the shaped inserts such as door lock apertures fuel fillers which are needed for incorporation into film infused panels.

Benefits of Short Line Technology

For the first generation of composites cars it was calculated that the short line saved about £70K in Work in progress. Scaling this up for the higher production rates and longer value streams it could be expected that the process village approach, producing at a rate of 4 per day might require an additional £7M of work in progress.

Most importantly though, short line technology splits the production line into small cells each of which can be paced to TAKT time. By splitting the work in to parallel streams the Operations specialist have significantly reduced the effects and risks of variability. Problems can be isolated while the line remains stable and predictable. In due course problem solving evolves into constant improvement.

Short Line Technology reduces the time from start to finish by two thirds which makes the factory very responsive to model changes. Surprisingly some companies have found that Short Line Technology combined with CONWIP production control algorithms can satisfy very short run customers such as Formula 1 racing teams.

Quality

What is good quality? Is it a class A finish out of the mould? Is it good consolidation? Is it out of autoclave processing? No, none of these are enough on their own to make a flow line work. Operations Managers need the process to perform the same every time. If necessary minor rework can be built into the line, rework influences cost not output.

A process which performs as expected would be allocated a process capability of 1 and this means that 99.7% of the parts would be right first time. Stand up the composites engineer who can guarantee less than 3 failures per thousand parts! For the first generation component we achieved a process capability of about 0.7, no figures have been published for the second generation, Is it any better?

Enabling Factors

To make Short Line Technology work there are 3 enabling factors:

1. A sufficient supply of multi skilled labour. Short Line Technology requires an increase in skill levels and this means a planned approach to training.
2. High Process latitude of materials, so that parts can mixed through bottleneck resources.
3. Acceptance in the costing that there will be a degree of overcapacity (waste) in all cells except the bottleneck.
4. An effective Kanban regime which prevents the parallel cells running ahead when they don't need to.

Conclusion

The array of processes available for the next generation of advanced composites cars is considerable, all have their merits, but all are still relatively variable when compared to traditional steel. With careful thought, and Short Line Technology it is possible to cope with this variability.

The objective of the composites community needs to be the achievement of consistent one shot processing, with attention given to a numeric assessment of process capability against a standard test pattern, which Operations can build their models and simulations.

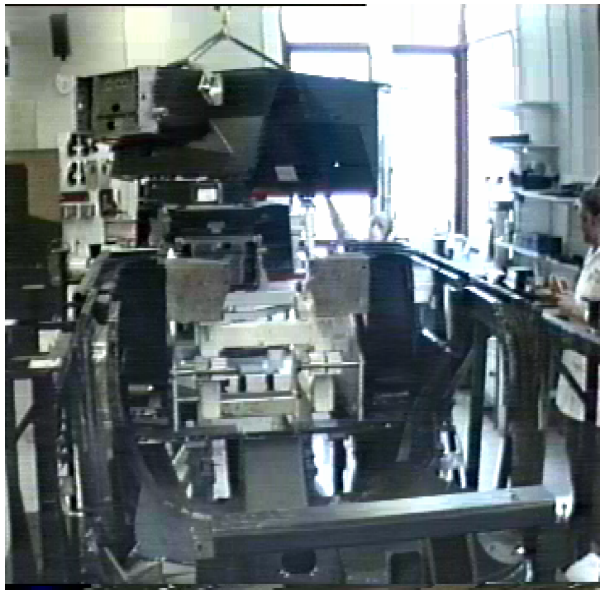

Fig 4 The true bottleneck in our factory was not the autoclave but the assembly jig

Operations Alternatives

In Operations circles there is debate about the way production should be organised. The two opposing views are those of Taiichi Ohno (Toyota Manufacturing System) and Eliyahu Goldratt (Theory of Constraints). The preferred solution in the automotive industry is the Toyota Manufacturing System.

Experience suggests that the Theory of Constraints is a more suitable approach for advanced composites. This states that the maximum output of a factory is determined by the bottleneck process, obvious isn't it? To operate the Theory of Constraints the bottleneck should be identified, and everything else in the factory made subservient to it.

The practical trick is finding the bottleneck. After some initial development work we found that the bottleneck was not where it had been assumed, the autoclave, but was in fact the assembly jig. By focussing initially on the autoclave the team were able to increase capacity to the point where it was no longer a bottleneck. This was achieved by stretching the process latitude of the raw materials so that mixed tools could be run in the autoclave. Having found the true constraint, the production controls, principally the formal Kanbans, and the other informal controls, could be manipulated to keep the jig running, providing a simple and very effective focus.

For reference the two competing Operations Philosophies are the Theory of Constraints (ref The Race by Goldratt and Cox ISBN0-888427-062-9) and the Toyota Production System (ref A Study of the Toyota Production System by Shigeo Shingo ISBN 0-915299-17-8)